Dan Levine
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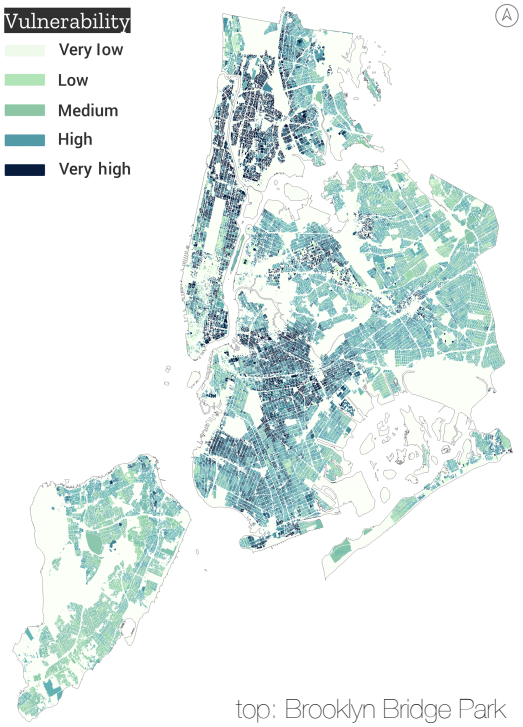
How the NYC Parks Department can use urban forest analysis to reduce flood risk



top: Brooklyn Bridge Park
bottom: hazard vulnerability[1]

Executive summary

Flooding caused by extreme rainfall is an urgent and growing threat to New York City. Hurricane Ida demonstrated the deadly and catastrophic consequences of climate change and particularly the vulnerability for the City's low-income residents and communities of color.

One of the fastest and most cost-effective ways to mitigate the city's flood risk is by expanding green spaces and adding trees which can naturally absorb and slow stormwater. As stewards of the City's street trees and green spaces, the NYC Parks has a vital role to play in the resilience effort. As new attention is paid (and new funding committed) to flood prevention, it is critical to understand where green assets can mitigate flooding.

Newly available data and technical tools can predict flood vulnerability and evaluate the capacity of street trees, natural areas, and green infrastructure to reduce the risk of catastrophic flooding.

NYC Parks has track record of success using emerging technologies to manage natural resources and it has forged successful partnerships with other City departments and outside entities.

NYC Parks should partner with an outside research entity to analyze and predict where trees and green spaces can reduce the greatest flood vulnerabilities.

The resulting maps and analysis can direct planning for green infrastructure and prioritize projects as the city makes increasing funding commitments to flood mitigation projects.

New York City faces a growing flood risk

Hurricane Ida's tragic consequences are a warning: flooding caused by extreme rainfall is an urgent and growing danger for New York City.[2]

Climate change will increase the threat of flooding

Two record-setting rainfall events this summer are a sign of things to come. Hurricane Ida dropped more than 3 inches of rain in an hour, nearly double the most severe deluge recorded before this year.[3] Such once-extreme events will become more common as the climate changes.[4] The most extreme storms are also the most likely to be locally concentrated, creating conditions more likely to produce flooding.[5]

Flooding puts vulnerable New Yorkers most at risk

New York City's flood risk is inequitable. Many neighborhoods home to low-income residents and communities of color are at greater risk of flooding (in part because of historic underinvestment in infrastructure in these segregated neighborhoods)[6]. Moreover, the economic precarity of marginalized communities makes them more vulnerable in disasters.[7] Most of the victims of Hurricane Ida's floods were residents in substandard, unlicensed basement apartments which are some of the only affordable housing options available for lower-income and immigrant New Yorkers.[8]

Traditional sewer infrastructure can't keep up

It is not possible to match the growing flood risk with expanded sewer capacity alone, and certainly not within the urgent timeline climate change imposes or at a reasonable cost. A sewer expansion project for a single flood-prone section of Queens is expected to take 15 years and cost $2 billion.[9] Expanding sewers citywide to sufficiently handle increasing rainfall would take decades and could cost up to $100 billion.[10]

Flooding in New York City during Hurricane Henri

Flooding caused by extreme rain is a city-wide challenge

Unlike the flood risk from coastal storm surges or rising rivers, which is limited to shoreline areas, internal or urban flooding can occur almost anywhere in the city when stormwater runoff overwhelms the local sewers.[11]

Heavy rainfall causes flooding when natural hydrology and the sewer system cannot drain downpours as quickly as they fall. In a natural landscape, rainwater might drain into the soil or pool in wetlands, but in the city's overwhelmingly urbanized landscape, stormwater collects on streets, sidewalks, parking lots, building rooftops, and other "impervious surfaces" and then rushes into the sewer system. Bursts of rainfall overwhelm the sewer capacity and backed-up water pools on hard surfaces creating floods.

Green infrastructure can mitigate flooding

Adding street trees, natural spaces, and green infrastructure in place of current pavement and impervious surfaces will be an effective and budget-conscious way for the city to reduce flood risk.

Trees, natural landscapes and green infrastructure absorb rainfall, slow stormwater, and reduce the flows that exceed sewer capacity.[12] This approach to managing storm flows is necessary as more extreme rainfall will overwhelm the existing sewer system.

As the steward of the City's street trees, parks, and many green spaces and natural areas, NYC Parks should be a leader in the citywide effort to combat flood risk through green infrastructure. This is an opportunity for the agency to lead on a pressing City priority.

Yanweizhou Park in Jinua, China

Learning from global leaders

New York City is already investing substantially in green infrastructure to reduce pollution flowing into the City's waterways by the outdated, overtaxed sections of the sewer system. Philadelphia, Washington, D.C., Chicago, and several other American cities with older combined sewers have made similar investments.

New York City can learn from cities around the world that are building and restoring city-scale natural systems to absorb and manage stormwater.

Singapore's "Active, Beautiful, and Clean" water management program has rebuilt concrete channelized drainages as meandering streams through wetlands that are designed to naturally retain flood water. China has adopted a "sponge city" framework for its rapidly growing cities and designs for green areas to absorb and filter floodwater. Copenhagen pioneered many green infrastructure strategies within a coastal city and its designs have influenced planning here in New York.

Flood prevention is a political priority and new funding is available

The tragedy caused by Hurricane Ida in 2021 has focused political attention on the risks of extreme rainfall and internal flooding. The City boosted funding for green infrastructure this year with an aim to make quick progress toward reducing flood risk.[13]

Additional funding is likely: Mayor-elect Eric Adams called for devoting 1 percent of the City budget to the Parks department (a 60 percent increase to the agency budget, based on current spending levels), with funding specifically devoted to "smart climate infrastructure such as recreation spaces that can double as water retention areas in emergencies."[14]

Hunters Point South Park, Long Island City, Queens

Additionally, the recently passed federal infrastructure bill offers new funding for flood prevention. Though funds are not earmarked for New York, there are considerable grant funds available, including $1.4 billion for cities for projects that reduce sewer overflow and stormwater flooding and an additional $3.5 billion for grants to projects that will reduce risk to properties insured by National Flood Insurance Program.[15]

Increased funding can allow NYC Parks to expand their workload and focus on areas at risk of major flooding. This year, the department responded to a one-time boost in funding by advancing wetland restoration projects, which it had already identified and planned, that met the mayor's storm resilience priority. Senior staff in the Natural Resource Division suggest that with an ongoing budget commitment to storm resilience projects, the Division would increase its planning efforts around this goal to identify additional suitable projects.[16]

Need to identify priorities and opportunities

As the city seeks to make urgent investments to reduce flood risk it needs plans identifying where and how to mitigate that risk.

New data and analysis tools can help pinpoint the locations where green interventions will most mitigate risk, especially to the most vulnerable New Yorkers.

Glossary

Street trees: Trees planted along sidewalks, medians, and elsewhere in the street right-of-way. Trees catch rain and block it from the street below and tree roots absorb stormwater, diverting some flow from the sewer. Greenstreets or curbside rain gardens also capture and retain some stormwater. Trees offer numerous other benefits, as well, including shading the city from heatwaves, filtering air pollution, and creating more aesthetically pleasing streetscapes.

Green space and natural areas: New York City has a diverse range of natural areas, including parks, forests, wetlands, and marshes. Healthy natural areas can absorb and retain rainfall.

Green infrastructure: In addition to the natural features, green infrastructure includes purpose-built in-ground retention areas to hold storm flows. These constructions can be placed beneath parks, recreation fields, or other open spaces to increase the water retention capacity of such open space.

All of these types are important to reduce the City's stormwater flows and flood risk. Different types are appropriate in different contexts. A full green infrastructure plan will need to consider the

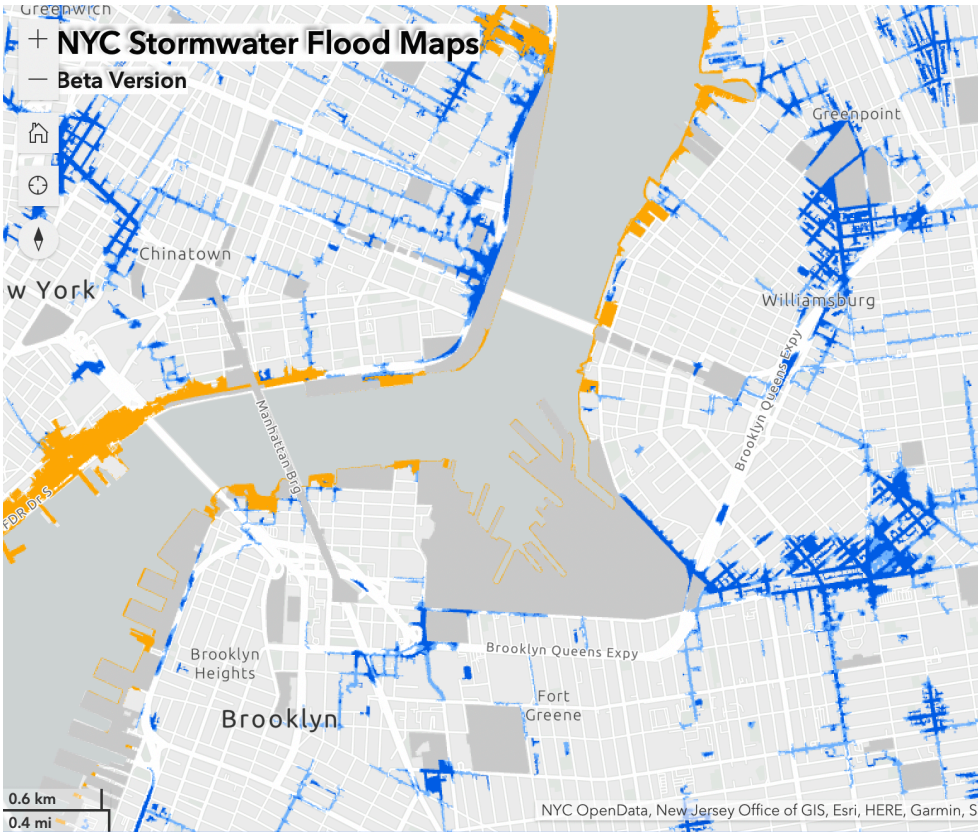
New data and analysis will tools support critical analysis

Newly available data and cutting-edge analysis tools can predict the flood risk and vulnerability across New York City and evaluate where and how much trees and green spaces mitigate this hazard.

Mapping flood risk and vulnerability

New studies offer the first predictions of internal flood risk across hydrologically complex New York City. Modeling this type of flooding is a computational and scientific challenge. Internal flooding can occur far from coastlines and is dependent on local sewer capacity and numerous other hyper-local factors.

Predictions for this flooding are now available for the first time through an analysis led by the Mayor's Office of Climate Resiliency (MOCR) and Department of Environmental Protection (DEP). The first product is a set of citywide flood risk maps that project flooding in different extreme rain scenarios.[17] The maps were released in May 2021 along with the mayor's plan for stormwater resiliency.[18]



NYU's Flood Sense project is collecting valuable data on actual flooding events which can calibrate and improve this model.[19]

Several experimental models use machine learning and statistical approaches to offer even more accurate flood hazard predictions.[20]

Data to redress inequity: flood vulnerability maps

As a next step in the flood mapping project, DEP will use flood *hazard* maps as a basis for flood *risk* maps.[21] Risk evaluation considers not just the flood water itself, but the physical and social factors that affect how much damage a flood may cause and how much capacity a community has to defend against and respond to a disaster. Flood risk evaluation follows a similar project to map the danger of extreme heat, quantified with a multi-faceted Heat Vulnerability Index.[22]

This information will be vital for identifying and planning for future green infrastructure projects and allow for analysis of where additional trees and green spaces will particularly reduce threats to the most vulnerable populations.

Modeling how trees and green infrastructure mitigate risk

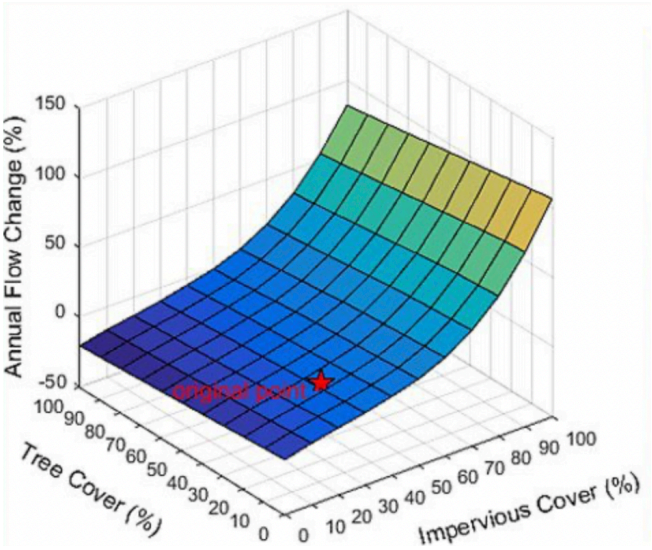
Trees and green spaces are extensively mapped, but their precise flood-mitigation effects need to be evaluated. Several cutting-edge analysis tools will allow for predictions of how street trees, natural areas, and green infrastructure can reduce anticipated stormwater.

Analyzing trees

i-Tree is a suite of computation and mapmaking tools to evaluate how trees impact the surrounding environment. The tools have been built through collaborations of academic researchers, NGOs, and governments. They are made freely available by the U.S. Forest Service.[23] NYC Parks Natural Resources Group has used i-Tree modules for modeling shade cover, forest composition, and hydrology in test locations.[24]

The i-Tree Hydro models focus specifically on modeling water flow effects of trees and green infrastructure.[25] i-Tree HydroPlus, newly released in October 2021, is a detailed tool that allows precise calibration to actual environmental parameters.[26]

These tools offer peer-reviewed, accurate estimates of flood impacts. They are free to use and can model current conditions and predict future flows. They produce fine-grained analysis, but are limited by the resolution of the input data. (For example, the i-Tree Hydro requires a stream flow gauge to calibrate water flow, but there is only one such gauge in all of New York City.[27]) Technical expertise will be required to match the new flood risk maps with the i-Tree tools.



i-Tree Hydro analysis

Analyzing natural areas and green infrastructure

Several tools offer analysis of how other green infrastructure features reduce stormwater flow.

The Stormwater Management Model is the benchmark tool created by the U.S. EPA to evaluate flood mitigation.[28] The well-established tool is used worldwide for planning and analysis of storm runoff. It performs hydraulic and hydrologic simulations, including in complex urban environments. Its models account for various green infrastructure interventions that reduce flow. The tool is open-source and free to use.

ArcGIS Hydro is a proprietary tool available through ESRI that models flood mitigation. DEP uses this software, along with a mass balance model measuring water volumes, to evaluate the mitigation capacity of specific green infrastructure projects.[29]

Experimental optimization tools can suggest precise locations where green infrastructure can most effectively reduce flows.[30]

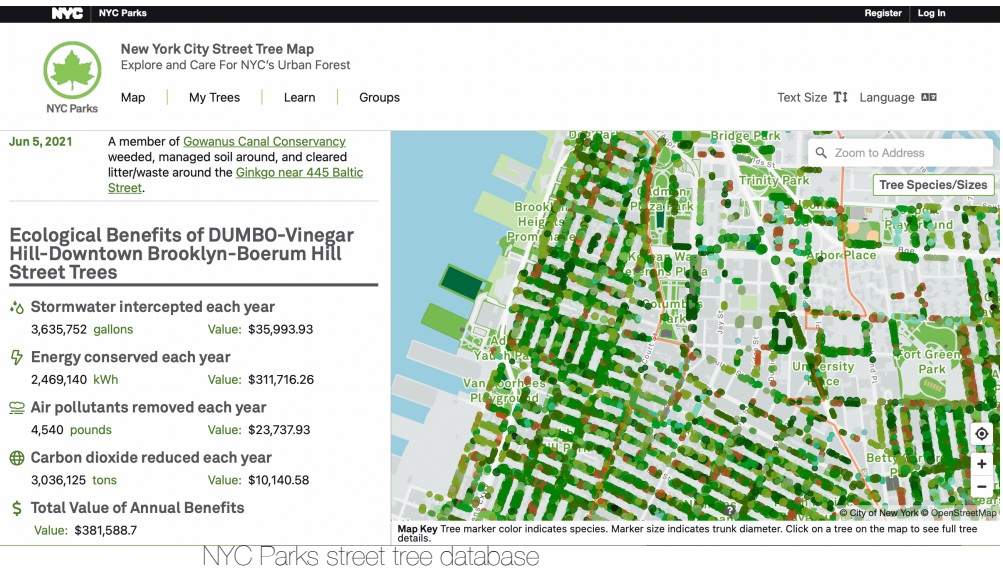
Analyzing and optimizing green infrastructure

These analysis tools, calibrated to New York City's actual flood history and predicted flood risk, can describe how current green infrastructure mitigates flood risk and predict how future green infrastructure would reduce risk. These analyses will help optimize green infrastructure addition and improvement to areas where it will most reduce predicted vulnerability.

Overall, this analysis will point to the locations where flood mitigation is most critical (particularly to reduce the threat to more vulnerable New Yorkers) and within those areas show the possible and feasible greening that can effectively reduce risk.

NYC Parks is ready to use technology

Parks' Natural Resource Division has been a leader in using technology for resource management. By digitizing field surveys in 1992 Parks became the *first* New York City agency to use GIS tools.[31] In 2010, the Group Natural Resources Group (the Division's research team) worked with the University of Vermont's Spatial Analysis Lab to obtain high-resolution land-cover maps based on aerial imagery and LiDAR.



NYC Parks street tree database

The Division has specifically evaluated the flood impacts of some of its environmental restoration projects. For the Staten Island North Shore Green Infrastructure plan, the department created a GIS model to identify priority locations for green infrastructure.[32] For a stream restoration study, The Division worked with the Spatial Analysis Lab to create GIS tools to assess stream flow and health.[33] The Urban Forest Assessment study, a project led by the U.S. Forest Service that included senior scientists from the Division, used i-Tree Eco to measure the impacts and benefits of the urban forest. A Bronx River case study for this report evaluated the specific flood reduction capacity of trees within this catchment basin.[34]

Planning green infrastructure must be a collaborative effort

Addressing the City's growing flood risk through innovative green solutions will depend on new and expanded partnerships between City agencies. Parks has built strong partnerships with other City departments and outside entities.

The partnership with DEP for green infrastructure is an example of intergovernmental success

Parks has a successful and well-integrated partnership with the New York City Department of Environmental Protection (DEP) to collaboratively plan and construct green infrastructure in parks.

DEP directly funds Parks' Forestry Division's work to plan and build green streets and underground stormwater retention beneath parks. This is a close collaboration: DEP funds specific staff lines within Parks' Forestry Division office and these staff liaise daily with their counterparts in DEP.[35] Parks and DEP have designed a mutually beneficial program so that these projects achieve DEP's requirements and also enhance Parks' assets.[36]

The City's stormwater mitigation projects have inspired novel partnerships between agencies, including Parks, DEP, and other land-managing agencies including NYCHA and the Board of Education.[37]

Collaborations with external partners are vital

The Division collaborates extensively with external partners for research and planning projects. For example, the U.S. Forest Service regional research station worked with Division scientists to study emerging management tools for New York City's urban forests and the Division has commissioned academic groups to use LiDAR sensing and machine learning tools to model the forest assets.[38]

The Division works closely with the Natural Areas Conservancy, an affiliated but independent non-profit organization, to plan landscape restoration and management.[39] These plans become valuable guidance for priority projects and help the Division gain additional capital grants or city funding for projects. For instance, when the mayor's office sought ready-to-go green infrastructure projects to accelerate in the urgent response to Ida, the Division used the wetland restoration blueprint to identify priority projects within Parks purview.[40]

MillionTreesNYC showed the City can deliver big greening initiatives (using data and ingenuity)

Planting the one millionth tree

The Department can emulate and learn from the successful MillionTreesNYC initiative, a recent example of a major project to expand the City's urban forest. This collaboration between Parks and the New York Restoration Project (NYRP) was launched as a public-private partnership under Mayor Bloomberg and delivered on its goal, planting the millionth new tree in 2015, two years ahead of schedule.[41] NYRP played a key role in forging connections between Parks and other agencies. It was also able to partner with private businesses and private landowners to plant trees on private land, which no city agency was permitted to do.[42]

NYRP used available maps of tree canopy cover and open land to identify the best opportunities to add tree cover. While Parks focused on planting on its own territories, NYRP worked with other agencies, institutions, campuses, and individual homeowners to get trees onto available plots of land.[43]

NYC Parks should partner with an outside expert to plan green infrastructure to reduce flood risk

The Department should initiate a new partnership agreement with an outside organization to develop green infrastructure management plans that focus on mitigating the greatest stormwater flood risk for vulnerable populations.

A partnership with an external partner will allow the Department to make use of outside expertise and set plans for future capital funding, without straying from its own mission.

The Natural Resources Division has a strong track record of valuable collaboration with government and non-government partners. Past and ongoing partnerships with the Natural

Areas Conservancy and University of Vermont Spatial Analysis Lab can be a model for a new collaboration focused on flood risk mitigation.

The Division has strong technical capabilities, but the most advanced modeling and analysis of flood risk is being developed by others and it makes sense draw directly on this external expertise.

Additionally, catastrophic flood mitigation is not directly within the mission of the Division. There may be some hesitancy to devote the Division's own staff and resources to this particular goal, or to publish internal plans the prioritize flood mitigation, as opposed to core goals of environmental restoration.

Nonetheless, the Natural Resources Group within the Division must be a close partner in this effort. They can contribute expertise on urban forestry and resource management practices and specific geographic and political constraints. Their involvement will ensure a workable, practical plan that aligns natural resource restoration and flood mitigation goals.

A successful partnership will produce maps and planning guidance that show how much green infrastructure and natural area restoration can reduce flood risk, particularly for vulnerable populations in high-risk areas. If this project is successful and persuasive, it will help secure and direct additional funding for tree planting or green infrastructure projects within priority areas.

At that point, the Division will be well positioned to manage the implementation and operations of planting and restoration projects.

Images

Page 1: Kristina Blokhin/Alamy Stock Photo; Yaella Depietri, Khila Dahal, and Timon Mcphearson.
Page 2: Stephen Smith/REUTERS
Page 3: Turenscape
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